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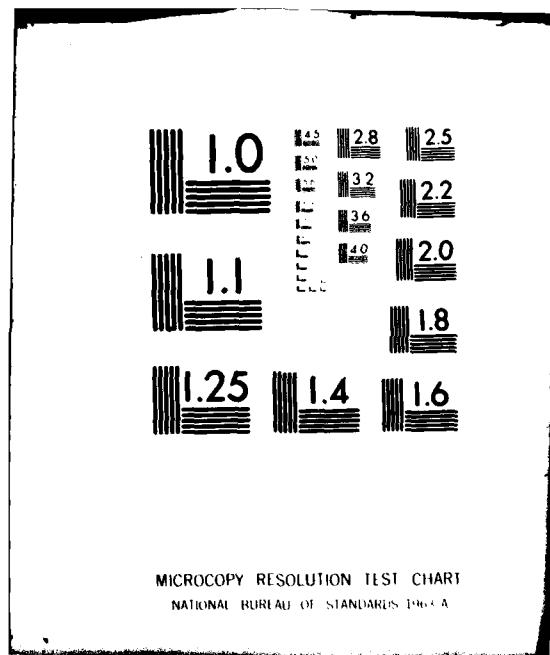
Development of a Unified Numerical Procedure for Free Vibration Analysis of
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)
The article presents the details of new numerical techniques developed in connection with the AFOSR grant. Thus a numerical algorithm and a computer program have been successfully developed for the efficient and economical solution of structural eigenvalue problems. Both spinning and nonspinning structures with and without viscous and/or structural damping may be analyzed by the routine. The program fully exploits matrix sparity associated with the finite and finite dynamics element formulation. In particular, effective solution of the quadratic matrix eigenvalue problem has been implemented for the development of finite

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20. Abstract cont.

dynamic elements. A special symmetric matrix decomposition scheme has been adopted for matrix triangularization that renders the program rather efficient.

Also, a novel bisection scheme has been developed that further accelerates the solution convergence rate, particularly for the case of repeated roots. Further, as a special case, the routine solves static problems with multiple load cases.

The associated computer program EIGSOL employs an out-of-core solution strategy, enabling effective solutions to be achieved for large, complex, practical structures. A listing of the program written in FORTRAN V for the UNIVAC 1100/82 along with the source deck is available for ready use.

SUMMARY

This report documents the research accomplishments achieved during February 1977 through January 1980 in connection with the AFOSR Grant No. 77-3276. During this grant period the R&D effort has been directed towards the development of the new concept of finite "dynamic" elements as well as a new generalized algorithm and associated computer program, for the efficient solution of a wide range of eigenvalue problems. Together, they constitute a powerful numerical tool for the economical and efficient solution of a wide variety of structural dynamics problems associated with complex practical structures such as aircraft and spacecraft, among others.

The results of the research effort have been published in journals of international standing as well as in proceedings of relevant international conferences. In an effort to effect imminent transfer of technology to the mathematical and engineering community, entire listings of associated computer programs have either been published in open literature or have been made available through appropriate public offices.

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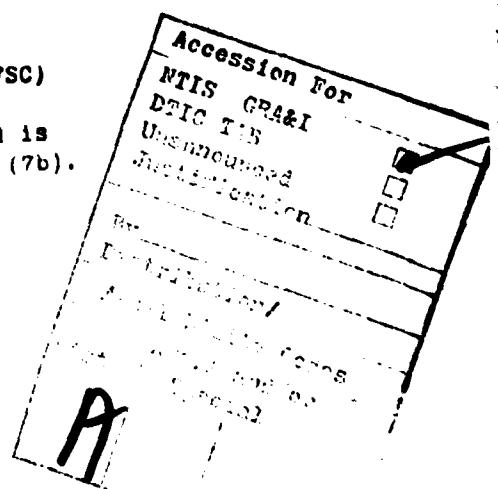
DEVELOPMENT OF FINITE DYNAMIC ELEMENTS

Two new dynamic elements have been successfully developed during the grant period. Thus, a rectangular plane stress/strain element was firstly developed to model two-dimensional elements. Next a general triangular plane stress/strain element was also generated to model more complex structural geometry.

The two elements were extensively used to model a wide variety of structures to afford a comparison of relative performances with the usual finite element method. Such results clearly indicate that dynamic elements are much more efficient than the commonly used finite elements. The two major benefits of the dynamic element method are summarized below:

1. For the same solution accuracy a dynamic element modeling effects a considerable reduction in the number of structural elements compared to the finite element model, thereby reducing the data preparation effort, considerably.

2. Most importantly, the dynamic element method is significantly more efficient than the finite element method, effecting a saving in solution effort by a factor between 2 and 5.

Results of these research efforts have been published in articles 1, 2,4 and 5 of the list provided later. These publications include complete FORTRAN IV program listing of the dynamic elements for ready use.

DEVELOPMENT OF A GENERALIZED EIGENPROBLEM SOLUTION ROUTINE

A new unified solution algorithm and an associated computer program has been developed for the efficient and economical solution of a variety of structural eigenvalue problems, including the quadratic matrix equations associated with a dynamic element formulation. The program is capable of solving a variety of problems as follows:

1. Free vibration analysis of undamped structures.

2. Buckling analysis of structures.

3. Free vibration analysis of structures with viscous and/or structural damping.

4. Solution of quadratic matrix equations for free vibration analysis employing a dynamic element modeling.

5. Free vibration analysis of undamped spinning structures.

6. Free vibration analysis of spinning structures with viscous and/or structural damping.

7. Solution of simultaneous equations, real and hermitian matrices.

The program EIGSOL based on a combined Sturm sequence and inverse iteration method automatically switches on to either the real or complex mode of operation, depending on the problem type that a user intends to solve. Other pertinent features of the program are summarized as below:

i. The program fully exploits the matrix sparsity such as usually associated with a finite and dynamic element modeling, requiring only the upper symmetric halves of the relevant matrices.

ii. An out-of-core solution strategy, involving only a moderate amount of core storage, enables solution of complex practical problems of almost any magnitude.

iii. A special symmetric matrix decomposition scheme has been utilized by the program that effects rather fast convergence to the roots and vectors. Also, the algorithm makes special provisions to ensure numerical solution accuracy.

iv. The program enables computation of a few desired roots and vectors only, without having to compute any others.

v. A novel bisection scheme has also been originated that effects much faster convergence to multiple roots, as compared to the usual techniques.

Details of this new algorithm and the program EIGSOL are published in articles 3 and 5 of the list, presented next.

PUBLICATIONS

The following publications provide the results of research effort conducted over three years in connection with the AFOSR grant.

1. "Development of a Finite Dynamic Element for Free Vibration Analysis of Two-Dimensional Structures", International Journal for Numerical Methods in Engineering, Vol. 12, pp 1311-1327 (1978)

2. "Finite Dynamic Element Formulation for a Plane Triangular Element", International Journal for Numerical Methods in Engineering, Vol. 14, pp 1431-1448 (1979)

3. "Development of a Unified Numerical Procedure for Free Vibration Analysis of Structures",International Journal for Numerical Methods in Engineering, to be published in October, 1980.

4. "Dynamics of Multibody Systems", invited paper, Proceedings of IUTAM Symposium, held in Munich/Germany, August 29-September 3, 1977.

5. "On Some Recent Developments in Numerical Methods in Structural Dynamics", invited paper, Proceedings of "U.S.-Japan Seminar on Interdisciplinary Finite Element Analysis", Cornell University, August 1978.

CONCLUDING REMARKS

During the duration of the 3 year grant period, most significant advances have been made in the area of numerical analysis pertaining to structural dynamics. New dynamic element formulations have been achieved along with the development of a new eigenproblem solution algorithm and an associated computer program. Results of these research effort have been published in important open literature. The associated computer programs, available for ready use, is expected to be widely used by the mathematical and engineering community.

ACKNOWLEDGMENT